Economic Impact of Climate Variability and Change on The California Water System

California Climate Change Center

Berkeley Water Group

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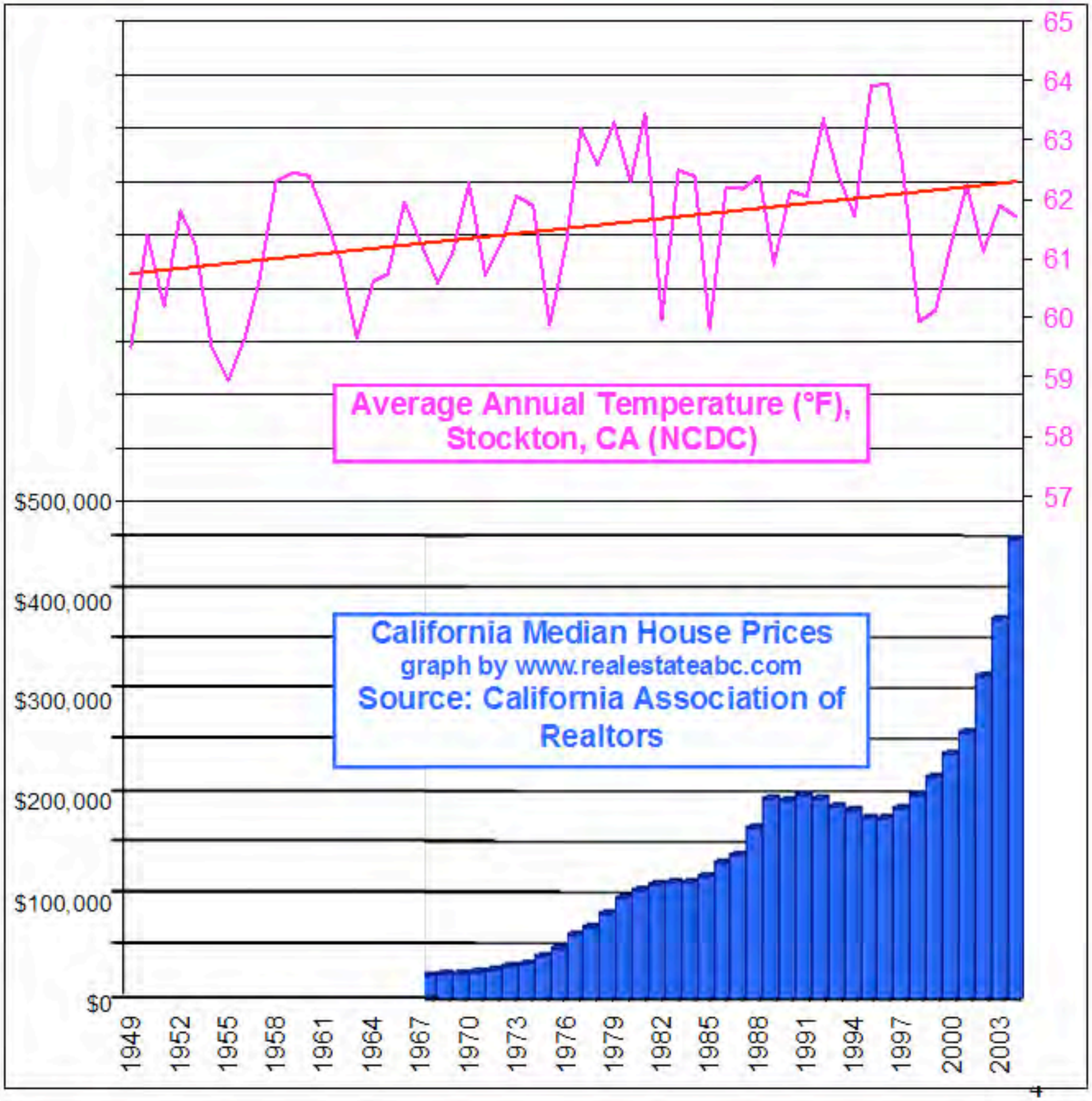
Research Questions

- How reliable is California's water supply?
- What is the cost of supply unreliability for agricultural, urban, hydropower, and in-stream users?
- How will climate change affect future supply reliability for different users?
- What are policy options for mitigating these adverse impacts?
- Other impacts of climate change?

Other impacts of climate change?



Ongoing projects at Berkeley

- Assessing state-wide climate change impacts on water supply reliability using CalSim II simulation model.
- Cost of supply unreliability for agricultural users. Focus on irrigation district level.
- Cost of supply unreliability for urban users.
- Impacts of climate change on long-term streamflow forecasting
- Impacts of climate change on high elevation hydropower generation stations.

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Assessing state-wide climate change impacts on water supply reliability using CalSim II simulation model

Follow up on PNAS paper published in 2004

Emissions pathways, climate change, and impacts on California

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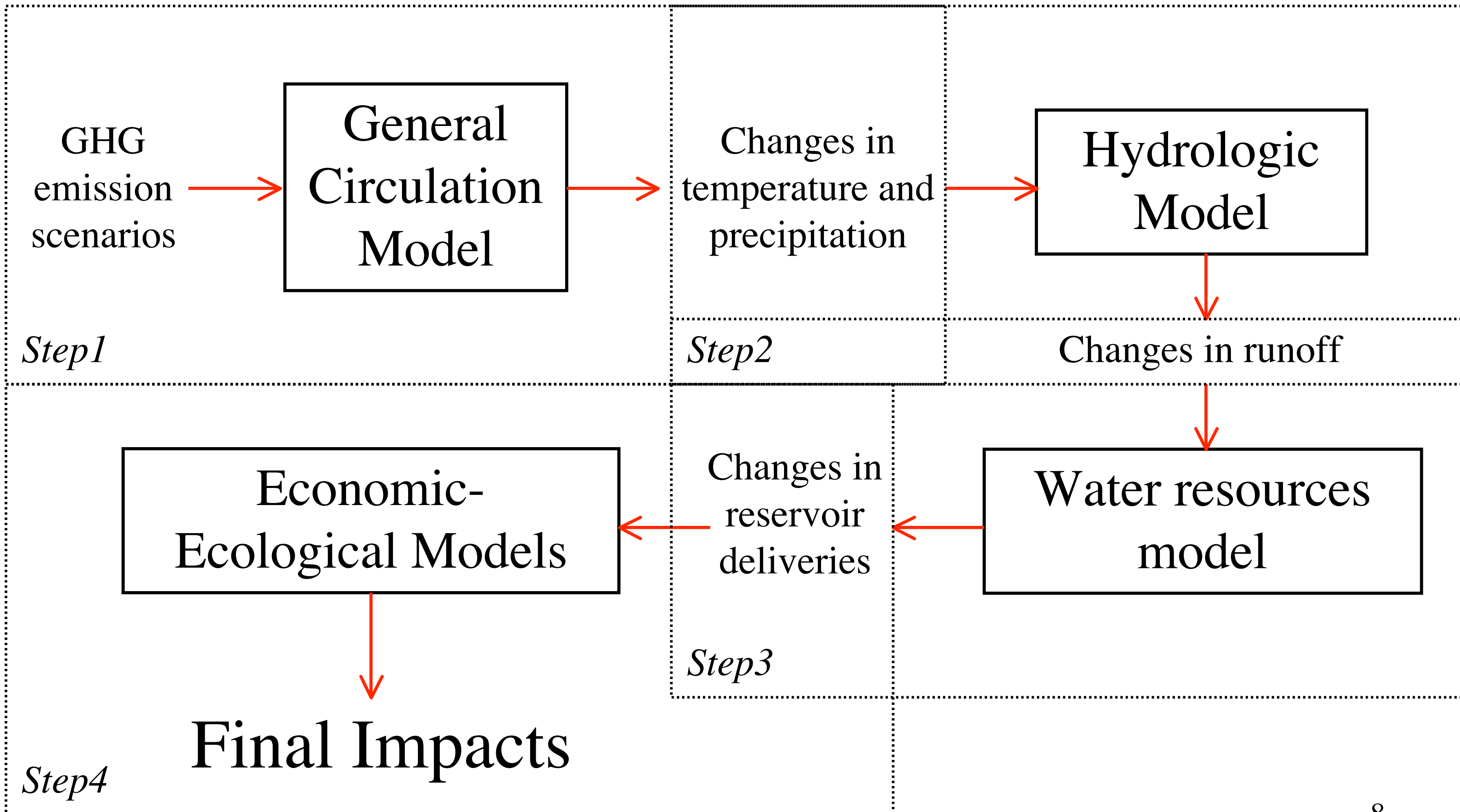
Contributed by Christopher B. Field, June 23, 2004

The magnitude of future climate change depends substantially on the greenhouse gas emission pathways we choose. Here we explore the implications of the highest and lowest Intergovern-mental Panel on Climate Change emissions pathways for climate

allel Climate Model (PCM) (3) and the medium-sensitivity U.K. Met Office Hadley Centre Climate Model, version 3 (HadCM3), model (4, 5) are used to calculate climate change resulting from the SRES (Special Report on Emission Scenarios) B1 (lower)

Assessing climate change impacts in water resources: methodology



Step 1: General Circulation Model

- We considered 2 GCMs:
  - Medium sensitivity: HadCM3 (Hadley Center, UK)
  - Low sensitivity: PCM (NCAR, US)
- We considered 2 GHG emission scenarios:
  - A1fi, high emissions
  - B1, low emissions
- We considered 2 time periods, mid century (2020-2049) and late century (2070-2099)
- Total of 8 scenarios
- GCM output statistically downscaled to hydrologic model resolution

Step 2: Hydrologic Model

- We used the Variable Infiltration Capacity (VIC) model (Liang et al., 1994; 1996)
  - Distributed macroscale model
  - Already used in Climate Change impact studies in California (Van Rheenen et al., 2004)
  - 1/8-degree resolution (≈150 km^2) over the Sacramento-San Joaquin river system

Step 3: Water Resources Model

- We used the CalSim II simulation model
  - DWR/USBR model
  - Considers major infrastructure and regulations
  - Runs using a time series of "73" years (1922-1994).
  - Already used in Climate Change impact study in California (Brekke et al., 2004)

Step 3: Water Resources Model (cont'd)

- We used the CalSim II simulation model
  - Historic time series was perturbed with monthly "perturbation ratios" (Average Monthly Inflow in Climate Change scenario/Historic Monthly)
  - Assumptions: static level of development and fixed water demands

Step 4: Economic-Ecological Model

- Still under development
  - Being built on the Natural Heritage Institute-Stockholm Environment Institute (NHI-SEI) WEAP Model of the Sacramento Valley.
  - Spatial focus at the level of individual irrigation districts.
  - With addition of economic choice of cropping pattern and irrigation technology based on observed behavioral relations, combined with temperature sensitive crop water demand.

Results Step 1: Climatic Variables

- Range of temperature changes increases by end of century:

  +2/+6ºC annual

  +2/+8ºC summer

- Range of precipitation changes by end of century:

  +38/-157mm (+7/-28%) annual

  +13/-92mm(+5/-34%) winter

Results Step 2: Hydrology

- Results dependant on scenario considered
- Snow water equivalent levels by end of century:

  -61/-97% all elevations

- Reservoir inflow by end of century:

  +12/-30% annual (increase in temperature not sufficient to counteract increase in ppt)

  -1/-54% April-June (effect of increase in temperature)

- Hydrograph centroid:

  -7/-32 days

- Impacts higher in Southern Sierra Nevada, especially by end of century
- Drier conditions than previous assessments: Brekke et al., 2004)

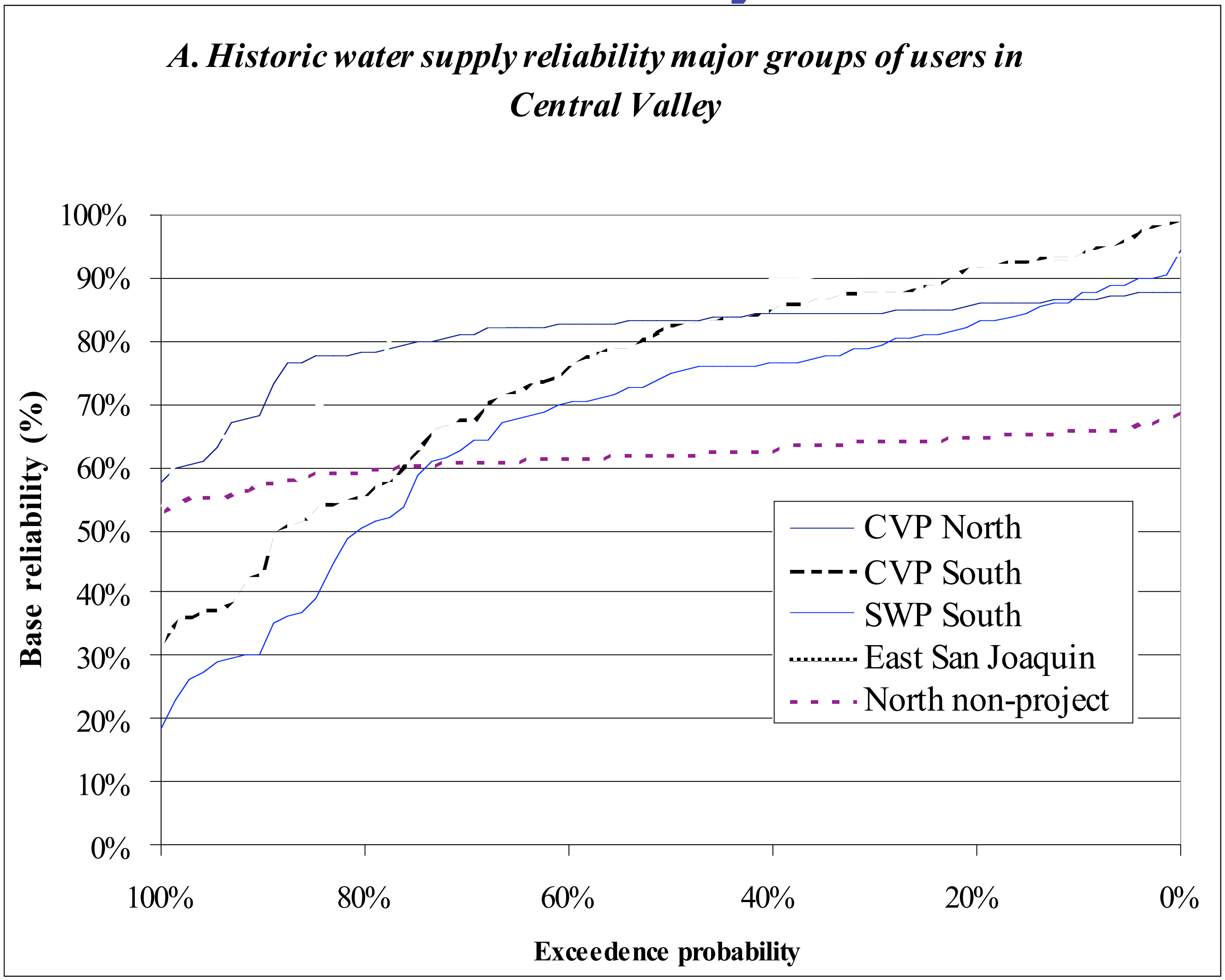
Results Step 3: Water resources impacts

- Metrics
  - Reservoir storage
  - Water supply delivery/reliability
  - Variables of environmental concern
- Results shown as exceedance probability
- Emphasis on water supply reliability

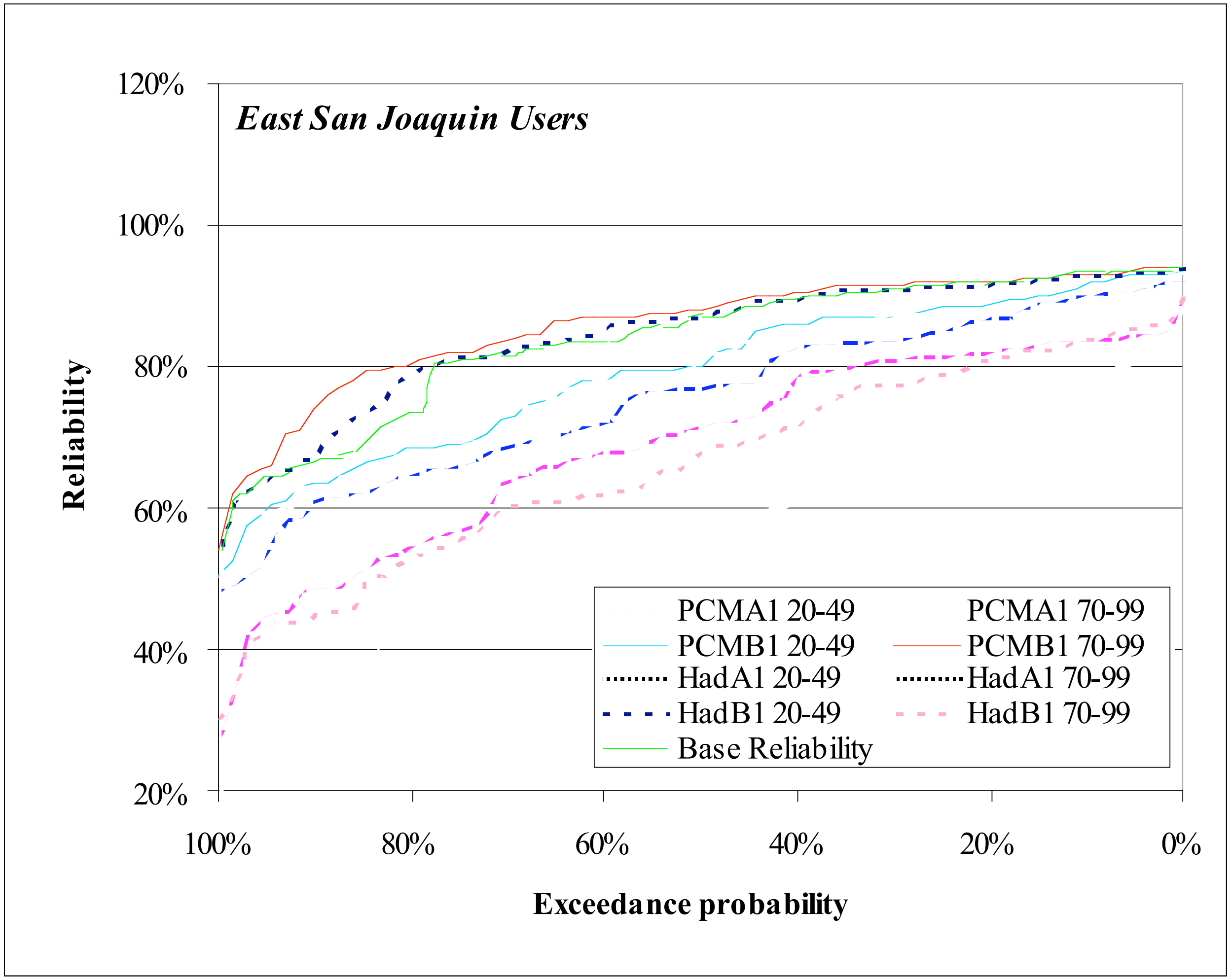
Results Step 3: Water resources impacts (cont'd)

- Impacts show a similar pattern to hydrologic changes
- Reservoir storage decrease
- Water delivery and reliability also decrease
- Impacts greater in southern Sierra Nevada, especially by end of century

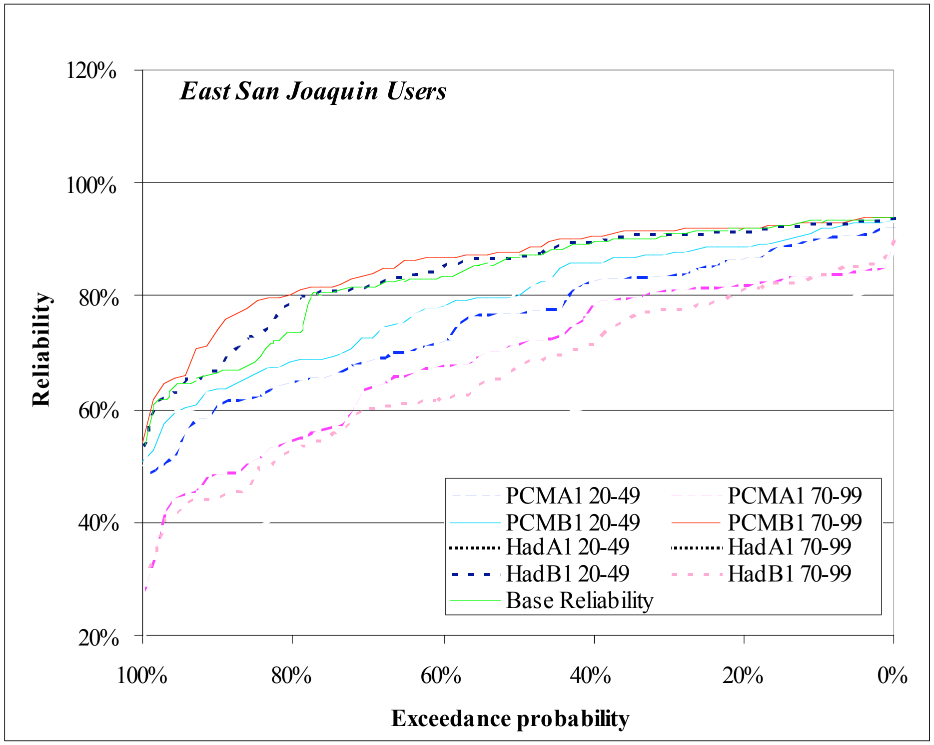
Results Step 3: Water supply reliability

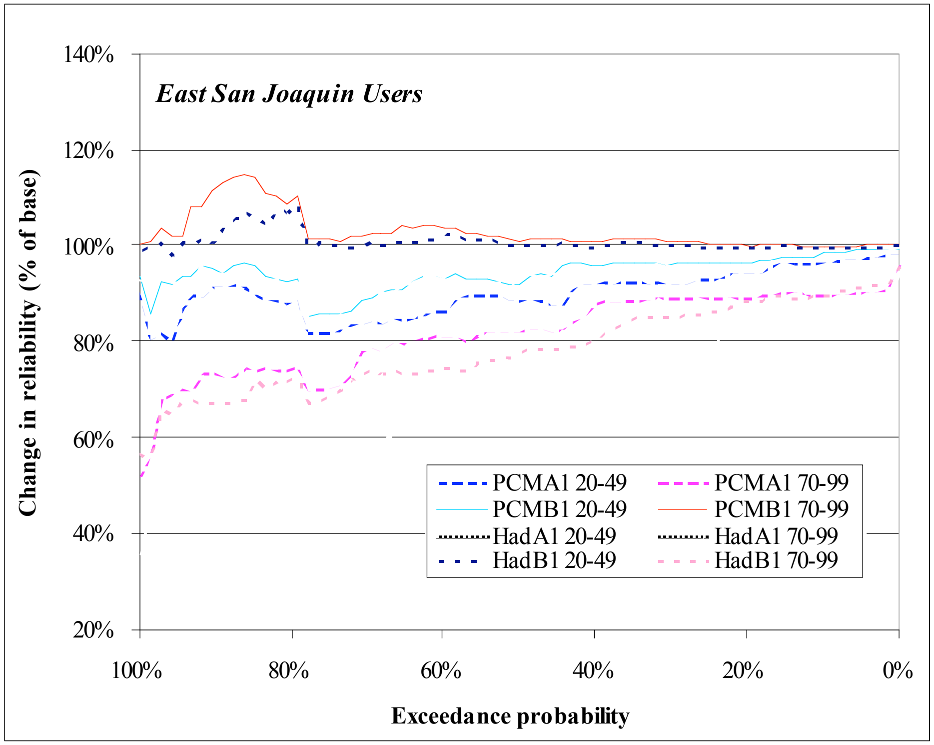


Results: Impacts on water supply reliability



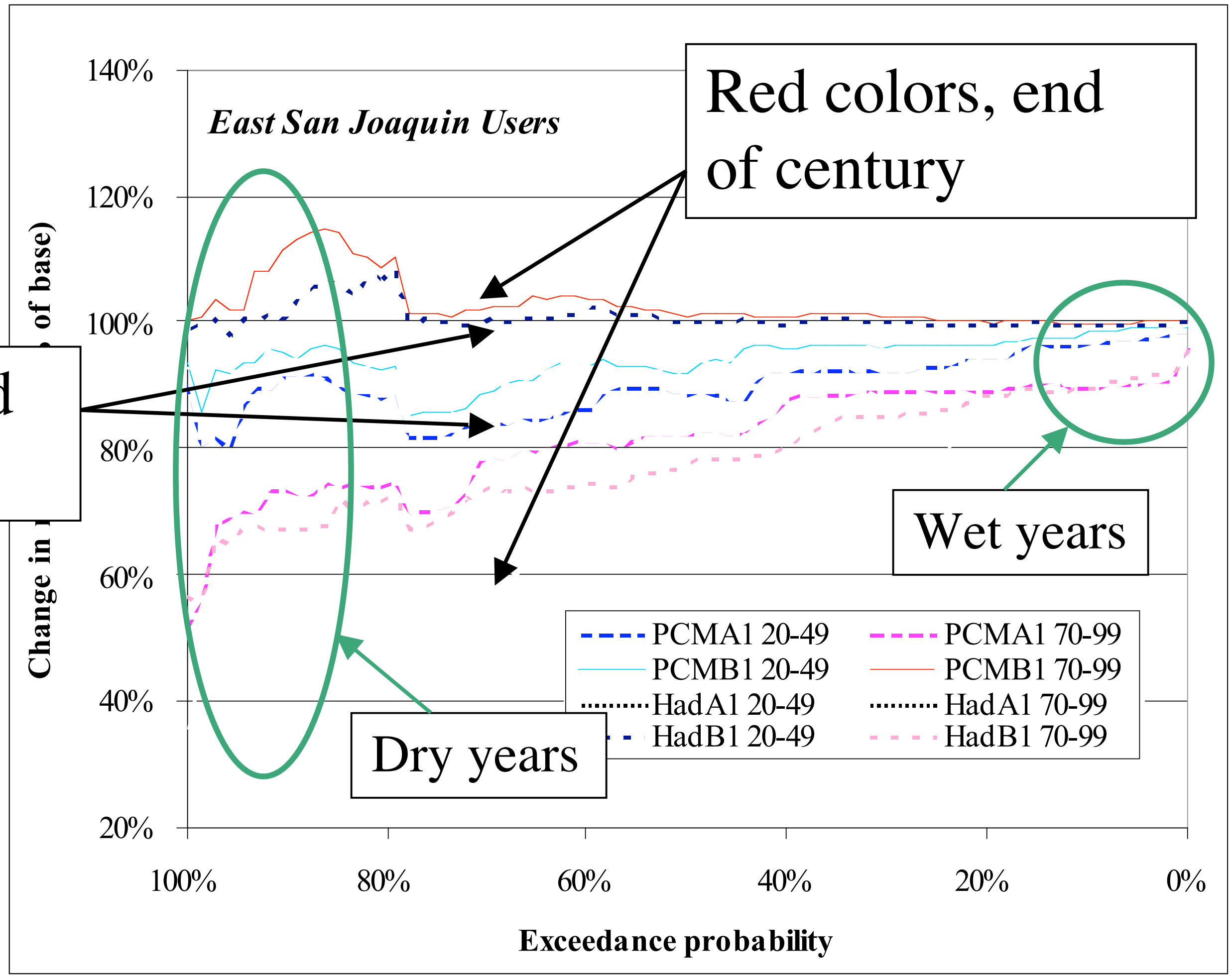
Results: Impacts on water supply reliability now shown as compared to historic reliability





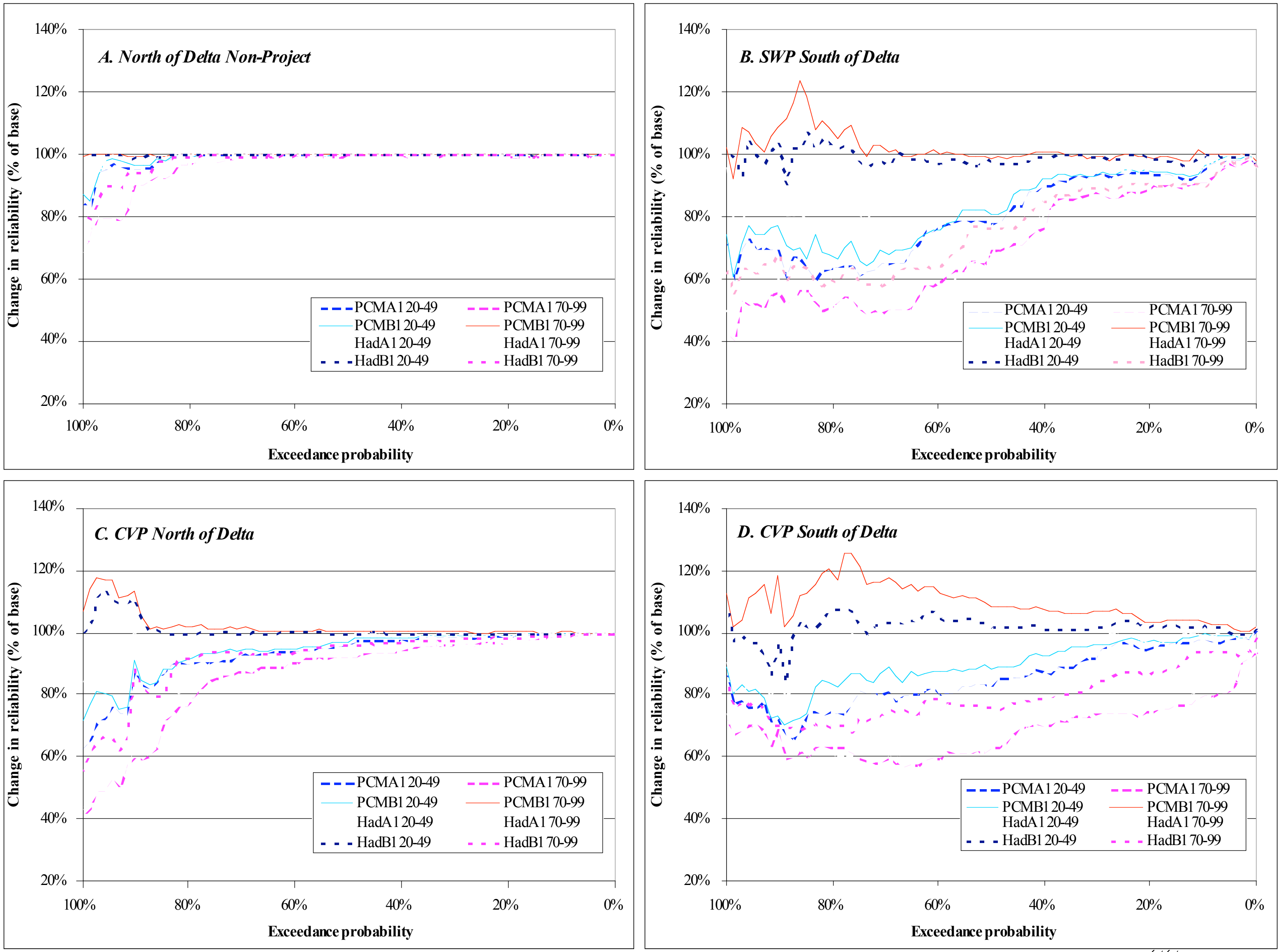
Results: Impacts on water supply reliability now shown as compared to historic reliability

- Results are more uncertain by end of century. Higher spread in scenarios
- Different relative impacts at different exceedance probabilities (i.e. for dry or wet conditions)



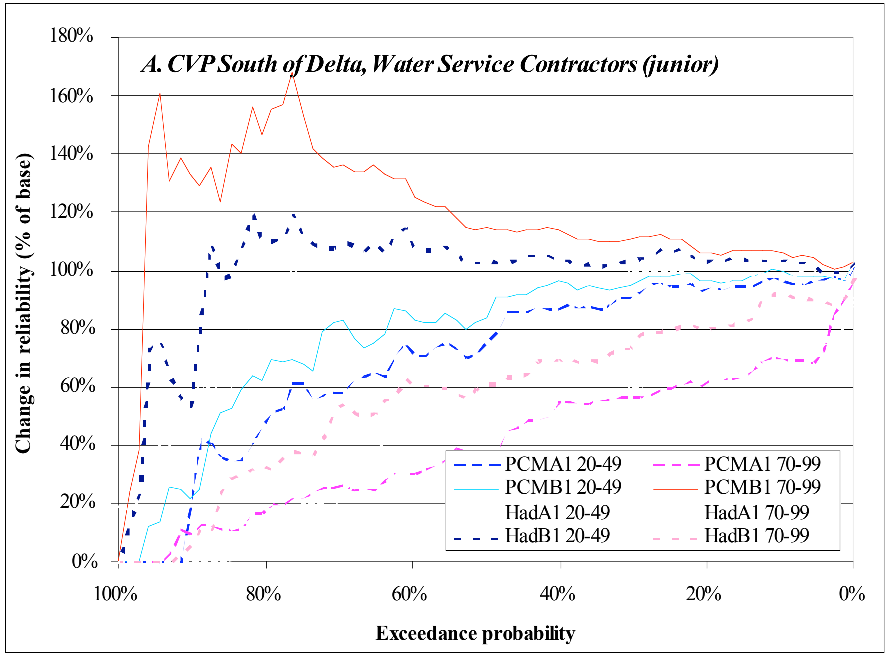
Water supply reliability, geographic differences

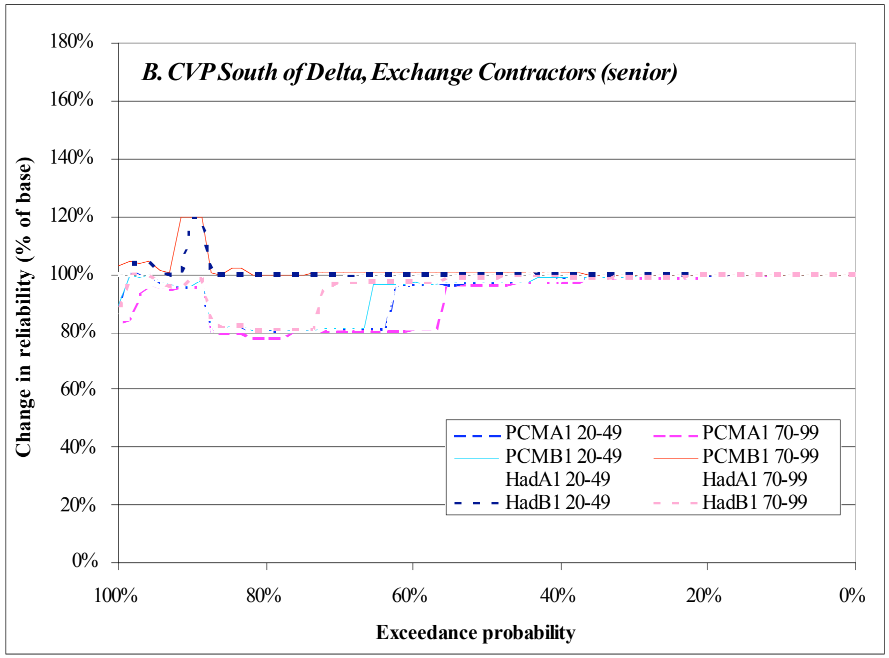
Impacts higher in Southern Central Valley



Water supply reliability:

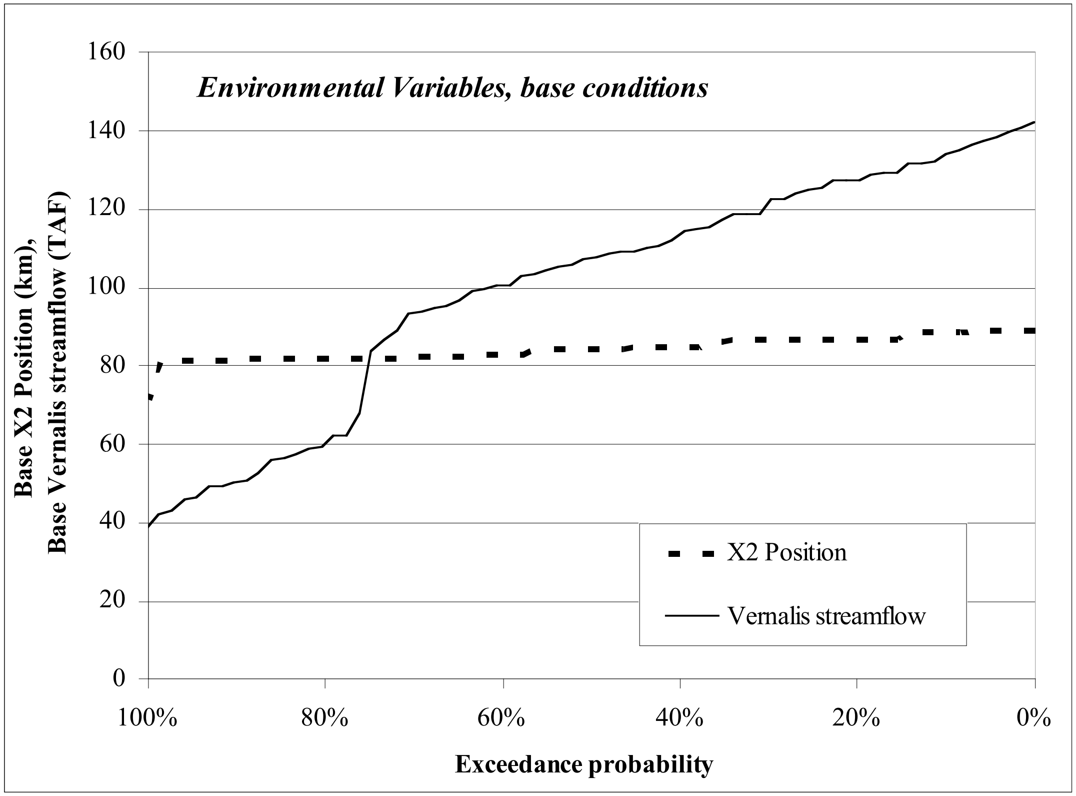
Institutional variability (water rights matter)





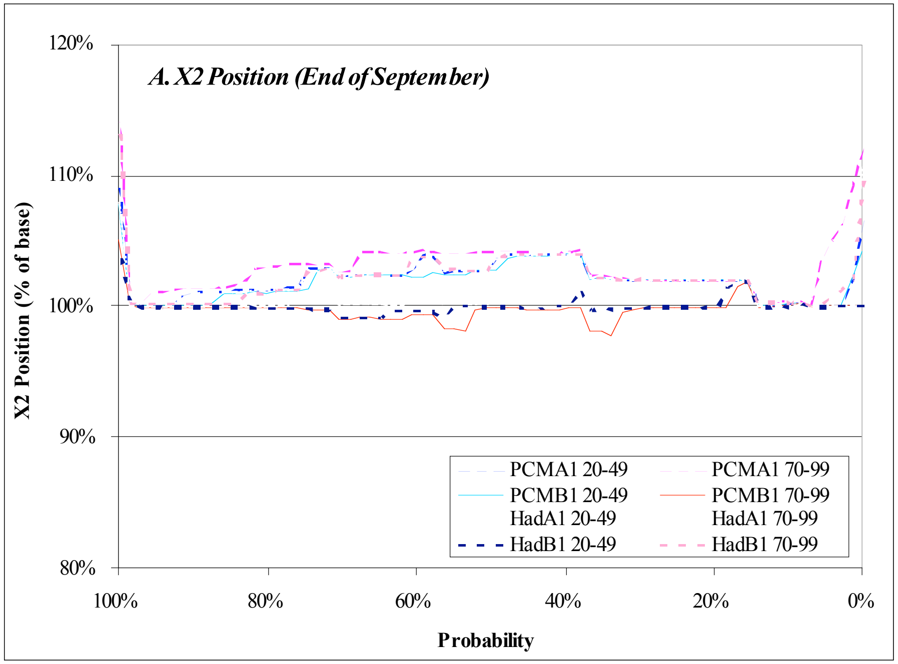
Results Step 3: Environmental impacts

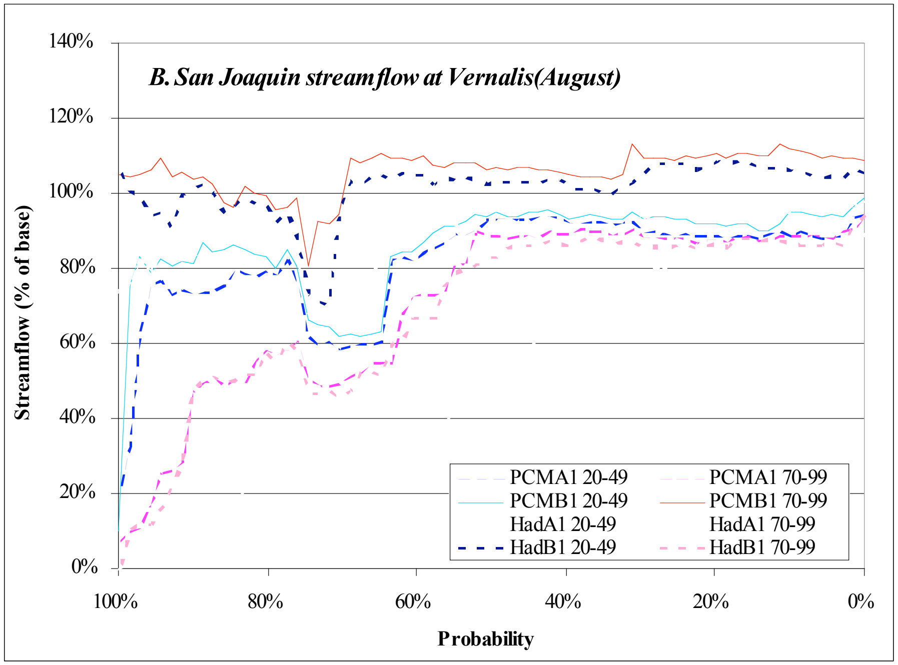
- Variables considered:
  - X2 position (position of 2 ppm saline concentration in Delta)
  - San Joaquin streamflow at Vernalis (dissolved oxygen)



Results Step 3: Environmental impacts

- Delta overall would not be affected according to CalSim II simulation which gives high priority to this variable
- Although, San Joaquin streamflows will be lower





Conclusions

- Latest GCM output shows higher impacts on California hydrology and water resources as compared to previous assessments
- Impacts higher by end of the century and in southern Central Valley
- Water rights and institutions do matter
- Important to consider not just average results but also impacts during extreme conditions

Future work?

- Develop more explicitly probabilistic analysis following Dettinger’s work
- Develop a comparative analysis of sensitivity of impacts to changes in precipitation versus temperature
- Include analysis of groundwater issues

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STAY TUNED!